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PERISTALTIC ROTATION PUMP WITH EXACT MECHANICALLY LINEAR DOSAGE

CROSS-REFERENCE TO RELATED U.S. APPLICATIONS

Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

NAMES OF PARTIES TO A JOINT RESEARCH AGREEMENT

Not applicable.

REFERENCE TO AN APPENDIX SUBMITTED ON COMPACT DISC

Not applicable.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to peristaltic rotation pumps with exact mechanically linear dosages. In particular, the present invention relates to peristaltic rotation pumps that are use in medicine, half-operation medicine production and in laboratories.

2. Description of Related Art Including Information Disclosed Under 37 CFR 1.97 and 37 CFR 1.98.

[0002] A peristaltic effect is based upon the gradual repeated ejection of a dosed media from a flexible container.

[0003] Gradual and repeated ejection of the media from the flexible container can occur on a circular occlusal path by pressing a pressure roller onto a flexible pump segment and simultaneous shifting of the roller in the direction of the longitudinal axis of the pump segment on the occlusal path so as

to pump the media.

[0004] Existing rotating peristaltic rotation pumps have been created solely for the purpose of achieving the pumping effect. All other objective criteria of pump quality, for example, accuracy and linearity of dosage, are less important in the prior art. In particular, the prior art cannot meet these qualities, in principle, since they are not able to fix the pump segment on the pump occlusal path and could not suppress the negative influence caused by the pressure roller when leaving the pump segment at the output of the pump.

[0005] An improvement in the technology was achieved by the microprocessor regulation of movement of the pressing element on the pump segment and/or the location of the pump segment in line with the gradual pressing by cams perpendicularly to the longitudinal axis of the pump segment. The pump segment is placed this way is fixed on the linear occlusal path. Since there is no movement of the pressing roller in the direction of the pump the longitudinal axis of the pump segment, its pre-stressing cannot happen and, thus, changes of cross section do not occur. The prior art fails to achieve any significant reduction in the negative influence of the pressing element when leaving the pump segment and the output of the pump. As used herein, the term "pump segment" replies to a tubular member onto which the pressing element exerts a force. This tubular element is typically in the nature of a tube used in the dispensing of medicines.

[0006] Microprocessor regulation of the non linear movement of pressure rollers has been utilized in multiple pumping cycles. Higher dosage accuracy and linearity can be achieved in this way when the smallest dose of the pump is specified. Non linear regulation would require different speeds of the pressure roller in different sections along the tubular element during a single pump cycle. This compensates for the mechanical non linearity of the chosen pump design.

[0007] Mechanical non-linearity of pumping in a single pumping cycle is primarily caused by cyclical constriction of the tubular element of the beginning of the occlusal path. This ejects a non-zero volume from the pump segment. Additionally, cyclical constrictions are also achieved by cyclical release of the tubular element after the end of the occlusal path. This causes expansion of the flexible tubular member and, thus, reception of the above described non-zero volume. This will cause a pulsing of the pumped media. There is also achieved a one-revolution non-linearity of the dosed media at the pump output.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention overcomes the principal drawbacks of peristaltic rotation pumps. In particular, this overcomes the overall substantial inaccuracy of the pumping and pulsing of the pumped media on the pump output during one revolution of the pump rotor. The peristaltic rotation pump of the present invention achieves exact dosing. The peristaltic rotation pump of the present invention comprises tubular element located on a working path within an outer housing. A rotor is provided with pressure rollers. The working path of the outer housing is grooved along the working path. The tubular element is received within this groove. There is circular supporting occlusal surface on opposite sides of the groove such at least two pressure rollers will roll along such an occlusal surface. These pressure rollers are slidably mounted in pressing blocks located in the arms of a triple-arm rotor. The rotor is connected to a shaft of a stepping motor. The occlusal surface is elevated in the central direction at an elevation above the bottom of the groove. The working path can include a first supporting surface, the occlusal path, and a second supporting surface. The first supporting surface is the lead-in path. The second supporting surface is the releasing path.

[0009] The tubular element is extended in the working path. The tubular element has a first portion

that is received against the first supporting surface and a second portion the is received against the second supporting surface. The tubular element forms a 90° angle with respect to the working path radius at the point at which the occlusal surface extends to either the first supporting surface or the second supporting surface.

[0010] Mechanical linearity of dosing is in ensured by the circular occlusal surface and the approximately circular releasing path. The annular length of the releasing path corresponds with the distance from the beginning of the releasing of the tubular element to the point of complete release. As such, it creates no force onto the pressure roller of the pump segment. This is the same as the angular length of the occlusal surface and the supporting occlusal path which is elevated above the bottom of the groove by a distance double the thickness of the wall of the tubular element.

[0011] The rotor is formed of a triple-arm hollow profile in which interior surface of the rotor contains a respectively plurality of pressure blocks in each of the arms. Each of the pressure blocks is defined by a longitudinal partition into a first part and a second part. A spring is located in each of the first part and the second part. The pressure blocks are secured in each arm of the rotor within the length of their strokes by a pin extending from the pressure block and into a groove formed in the arm of the rotor. The springs within the pressure block are urged against a back wall of the pressure block. A roller is freely mounted at the end of the pressure block. The springs are pre-stressed at the other end against a body located in the center of the rotor. The body is affixed adjacent to the shaft of the stepping motor. The body has a trilateral prism shape.

[0012] The trilateral prism shape of the rotor includes rounded ends which are received within respective sockets formed on the interior of the arms of the rotor. The body has a cylindrical protrusion on side thereof. A locking spring engages this cylindrical protrusion. The body has a

locking groove and an inlet groove suitable for receiving a locking pin placed on the shaft of the stepping motor. The locking groove and the inlet groove are formed on the backside of the body. The width of the locking groove has a width at an end opposite the shaft which is narrower than a diameter of the locking pin.

[0013] The pin of the pressure block fits into a first groove symmetrically located in the front part of the rotor. The pin locks also into another groove of the control element. The control element is threadedly connected to a cylindrical protrusion.

[0014] The pressure block has guiding groove for transversely guiding the tubular element along the grooved working path. The pressure roller is in the form of a roller bearing of a cylindrical shape. The pressure roller is rotatably mounted within the sliding mounting of the pressure block. The sliding mounting is provided with the wiping blades for removing possible dirt in both directions of rotation. There are sockets in the head of the pressure block adjacent to the wiping blades.

[0015] The pressure roller can be an electrical conductor. In particular, there can be position contacts located at the juncture of the occlusal surface with the first supporting surface and at the juncture of the occlusal surface with the second supporting surface. As the pressure roller moves and rotates, it can contact the electrical conductors. The contactors have a current of a very low voltage. Alternatively, the pressure roller may be magnetized.

[0016] The present invention achieves several advantages. By the expansion of the tubular element and its extension along an arch of a radius of about three to four times the radius of the occlusal surface, and by leaning the ends of the tubular element against the supporting surfaces, the basic radial pressure of the tubular element against the grooved surface of the occlusal path the tubular element achieves the desired basic radial pressure. The tubular element has a length that is two to

five percent longer than distance between the first and second supporting segments. The rate of "compression" of the length of the tubular element is adequate for the diameter and thickness of the wall of the tubular element. The tubular element is in a plan perpendicular to the main axis of rotation of the pump even after of a pre-stressing of its length.

[0017] The present invention prevents length wise shifting of the tubular element along its working path in the direction of the rotor rotation as a result of the grooving of the occlusal surface. The basic pressure forces the soft surface of the tubular element into the groove even when the pump is switched off. The groove has a transverse cross section of an isosceles triangle with a height of approximately 0.15 and 0.50 millimeters, depending on the radius of the tubular element and the thickness of the wall of the tubular element.

[0018] The transfer of the excessive compressing force of the pressure roller onto the supporting occlusal path prevents crushing or the occurrence of undesirable or even harmful force against the tubular element as a result of the movement of the pressure roller. The pressure roller rolls against the occlusal surface so as to avoid the crushing of the tubular element by an excessive force. It either cannot sink deeply into the tubular element by excess force and cannot create an undesirable shift force applied to the tubular element in the direction of its longitudinal axis. The level of the pressure exerted by the pressure roller is adjusted automatically for variable working conditions of the pump by redistribution of the total pressure force between the grooved working path with the inserting tubular element and the supporting occlusal surface. The fixed distance of the occlusal surface from the transversely grooved working path defines the extent of the grasping of the tubular element along the occlusal path. The positioning of the first and second supporting surfaces away from groove of the occlusal path assures that the volume ejected by the pressure roller from the pump segment is

only a result of the radial application of force onto the tubular element.

[0019] The source of pulsing caused by repeated releases of the compressed flexible tubular element cannot be removed. Any cyclical drops and increase of the ejected medium from pulsing at the pump outlet in one cycle can be removed mechanically if the mutually correct correlation of geometrical dimensions is observed. In particular, this is achieved by the equal lengths of the occlusal path and the releasing path for the guiding of the tubular element from the occlusal path. It is also caused by the constant increment of the volume of the tubular element at the gradual release of the pressure of the pressure roller on the releasing path related to any unit of its length regardless of the manner in which the tubular element is mechanically clasp within the occlusal path. Mechanical linearity of the peristaltic rotation pump in accordance with the present invention is ensured by the equal angle and lengths of the first and second supporting surfaces defining the occlusal and the releasing paths. This condition is also achieved by the three-or more-arm rotor.

[0020] The pump rotor arms are symmetrically arranged in a circle. The minimum length of the main occlusal path of the pump is the result of the formula in which 360° divided by the number of pump rotor arms. In the case involving the preferred embodiment of the present invention, the minimum length of the main occlusal path of the pump rotor is 120˚.

[0021] With zero back pressure at the pump output, only minimum pressure of the pressure roller is sufficient for closing the tubular element’s cross section. Any excessive force caused by the springs is compensated by reaction of the supporting occlusal surface onto which the pressure roller rolls. When the back pressure increases, it is necessary to increase the pressing force of the pressure roller. This happens automatically by reduction of the force applied by the same pressure roller on the supporting occlusal surface.

[0022] The pressure roller of either of the pump rotor arms rolls on the supporting occlusal surface at the place of concurrence and also along the tubular element placed along this working path. The pressing force of the roller is carried out by the sliding mounting of its surface in the pressure block. As a result, these advantages are achieved by the unique combination of the rolling and sliding friction of the pressure roller of the peristaltic rotation pump. This holds the reaction of the pressing force of the pressure roller and the sliding mounting of the pressure block of the pump rotor.

[0023] The position of the pump rotor in the pump housing occurs without dislocation of the pump segment along its working path. This position is required for reaching high pumping accuracy. The hollow profile of the pump rotor allows for the receipt of the pressure blocks. This allows the use of a compact space of the large possible diameter. As a result, there is a large stroke of the pressure roller.

[0024] The easily disconnectable attachment of the pump rotor onto the shaft of the step motor facilitates the ability to adjust the clearance of the rotor with respect to outer housing.

[0025] It is an object of the present invention to provide long-term and stable fixation of the tubular element along the working path of the pump.

[0026] It is another object of the present invention to provide an exactly defined distance between the pressure roller and the tubular element at each point along the pump working path.

[0027] It is a further object of the present invention to provide a mechanical split of the working path of the pump into two paths of identical length. These paths include the occlusal path of the pump and the releasing path for guiding the tubular element out of the occlusal surface of the pump. There is also a lead-in path of any length for guiding the tubular element into the occlusal path of the pump. These paths define the working path of the tubular element of each pump.

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[0028] It is a further object of the present invention to provide a mechanically constant increment of the tubular element volume by gradual releasing of the pressure roller from the tubular element located by the release path for leading the tubular element out of the occlusal path.

[0029] It is a further object of the present invention to provide pumping linearity by removing negative influences on the particular pressure roller.

[0030] It is a further object of the present invention to provide accuracy and long term stability of the pump so as to enable further substantial increases in doses accuracy through the use of microprocessor calibration.

[0031] It is an object of the present invention to provide a peristaltic rotation pump that can be easily manufactured in a uniform manner.

[0032] It is still a further object of the present invention to provide peristaltic rotation pump which avoids irreversible deformation of the tubular element.

[0033] It is a further object of the present invention to provide a peristaltic rotation pump which is exact and mechanically linear without regard to manufacturing tolerances on the individual mechanical components.

[0034] It is another object of the present invention to provide a peristaltic rotation pump which creates linear dependence on the dosed volume based upon the angle of rotation of the rotor.

[0035] It is still a further object of the present invention to provide a peristaltic rotation pump that is cheap to manufacture and does not require special installation or mechanical calibration.

[0036] It is a further object of the present invention to provide peristaltic rotation pump which has an extended life and a simple operation.

[0037] It is a further object of the present invention to provide peristaltic rotation pump that requires

a minimal amount of training.

[0038] It is still another object of the present invention to provide peristaltic rotation pump which allows a wide range of pumping parameters to be achieved from micro-litters to tens or hundreds of litters by a simple change of a few design parameters.

[0039] It is still another object of the present invention to provide peristaltic rotation pump that can be switched during the operation by a control in both direction of rotation with no change in accuracy and linearity of pumping.

[0040] It is still a further object of the present invention to provide peristaltic rotation pump in which liquids as well as gases can be pumped and dosed with the same accuracy.

[0041] It is still a further object of the present invention to provide peristaltic rotation pump that allows dosage accuracy to be achieved with minimal costs and to be used in a highly pure environment.

[0042] It is another object of the present invention to provide peristaltic rotation pump which has minimal manufacturing costs while achieving the desired accuracy so as to enable the pumps to be used where accuracy is not the decisive parameter, such as supplying nutrition in the digestive system, endoscopic operation of knees, sucking liquids from wounds, dialyses monitors, etc.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0043] FIGURE 1 illustrates schematically the arrangement of the outer housing with the pump segment and rotor located therein.

[0044] FIGURE 2 is an enlarged isolated view showing the illustration of circled area D from FIGURE 1a.

[0045] FIGURE 2 is an exploded perspective view of the peristaltic rotation pump of the present

invention.

[0046] FIGURE 3 shows a rearward upper perspective view of the pump as dismounted from the outer housing.

[0047] FIGURE 3b shows a rearward upper perspective view of the pump as dismounted from the outer housing.

[0048] FIGURE 4 is a perspective view showing an exploded view of the dismounted pump.

[0049] FIGURE 5a shows a frontal upper perspective view of the rotor body.

[0050] FIGURE 5b shows a rearward upper perspective view of the rotor body.

[0051] FIGURE 6a is a frontal upper perspective view of a pressure block.

[0052] FIGURE 6b is a rearward upper perspective view of a pressure block.

DETAILED DESCRIPTION OF THE INVENTION

[0053] The peristaltic rotation pump of the present invention includes a tubular element 1 having an external diameter of 3.9 mm placed along an inner surface of an outer housing 24. The outer housing 24 has a diameter of approximately 65 mm. A three-arm rotor 6 is shown as having pressure rollers 4. The tubular element 1 is a tube utilized in an infusion set that is normally available in medicine. A working path 2 is defined along an inner surface of the outer housing 24. This working path 2 is grooved at the point of contact with the compressed tubular element 1. As will be described hereinafter there is an elevated supporting occlusal path 3 along which the pressure rollers 4 roll. The pressure rollers 4 are slidably mounted in pressure blocks 5 fitted in arms 23 of the rotor 6. The pressure roller 4 is a cylindrical member or a rolling bearing having a diameter of approximately 9mm. The pressure rollers 4 can be formed of hardened and lapped steel. The rotor 6 has a three-arm hollow profile 7. The pressure blocks 5 are loaded within the hollow area of the

arms 23. Springs 8 are positioned within each of the arms 23. The springs 8 are located in the pressure blocks 5 and separated by a longitudinal partition 13. The springs are pre-stressed against the body 22 placed in the hollow profile 7 of the rotor 6. The body 22 has a trilateral prism shape having rounded corners 35. The rounded corners 35 fit into the socket 34 of the hollow profile 7 of the rotor 6 in the area of the connection of the arms 23 of the hollow profile. The body 22 has a cylindrical protrusion 29 at the front thereof. A securing spring 17 is placed thereagainst. A securing groove 19 is placed in the back side of the body of the body 22, along with an input groove 20, for securing pin 21 extending from shaft 9 of the motor 10. The width of the securing groove 19 at the location most distant position is shaft 9 is narrower than the diameter of the securing pin 21.

[0054] The tubular element 1 is mechanically compressed along the working path 24. In particular, there is first supporting surface 15, a second supporting surface 16 and a working path 2. The ends of the tubular element 1 will reside against the supporting surfaces 15 and 18. The supporting occlusal surface 3 is elevated above of grooved occlusal path 2 by the distance of approximately 1mm. The pressure block 5 is provided with a guiding groove 11 for guiding the tubular element 1 along the grooved working path 2. The stroke of the pressure block 5 is 7 mm. This is in the range of approximately 1.1 to 2 time the external diameter of the tubular element 1.

[0055] The pressure blocks 5 are secured within the rotor 6 by the use of a pin 12 placed in the front on the longitudinal partition of the pressure block 5. The pin 12 locks into the first grooves 14 symmetrically located inside the hollow profile 7 of the rotor 6. At the same time, the pin 12 also locks into the second groove 33 of the control element 32. Control element 32 is designed for handling the pressure blocks 5 when the rotor 6 is being mounted to the working path 2 into which

the tubular element 1 is pressed by expansion. The control element 32 is threadedly connected to the cylindrical protrusion 29. The groove 14 has a length of approximately 7mm. The rotor 6 is connected by the body 22 to the shaft 9 of the step motor 10 and support by securing spring 17.

[0056] The pressure roller 4 is an electric conductor. As an electrical conductor, it can contact the speed contact 25 or the position contact 26 located on the supporting occlusal surface 3 at the point of the change from the lead-in path 15 to the occlusal path 2. There is a common contact 27 located against them on the edge of the occlusal path 2. The electric current applied is of a very low voltage.

[0057] In order to prevent unintentional rotation of the control element 32 during operation of the pump, there are depressions 30 into which protrusions 31 lock onto the front side of the hollow profile lock 7.

[0058] In order to operate the present invention, the tubular element 1 is placed into the grooved working path such that the tubular element 1 covers the lead-in path 15, the occlusal patent 2 and the releasing path 16. The pressure blocks are shifted into the arms 23 of the hollow profile 7 of rotor 6 by use of the control element 32. As such, the rotor 6 is ready for free sliding into the outer housing 24. The input groove 20 of the body 22 is turned parallel with the locking pin 21 placed on the shaft 9 of the step motor so as to slide the rotor 6 on the shaft 9. It is the pressed against the securing spring 17 and turn by 30˚. Afterwards, pressure is released against the rotor 6. The pin 21 of the shaft 9 of the stepping motor 10 then locks in the securing groove 19 in the body 22 and the motor is connected to the rotor 6 without any play.

[0059] When the control element 32 is turned backwardly, the pressure blocks 5 slide out of the arms 23 of the rotor 6. As a result, the pressure rollers 4 will lean against the supporting occlusal surface 3 and also against the tubular element 1 located along groove of the outer housing 24. At the same

time, the guiding grooves 11 of the pressure blocks 5 are ready to guide the tubular element 1 transversely along the working path 2.

[0060] During each actuation, the peristaltic rotation pump of the present invention carries out an automatic functionality self-check by way of the electric position contact 26. This senses the position of the pump rotor 6. The contact between the pressure rollers 4 and the contactors 26 and 27 causes a conductive connection. The electronic system immediately, and with high accuracy, determines the number of steps of the stepping motor necessary to repeated turn of the rotor 6. The unit thus tests correct operation of all the moving parts of the pump rotor 6 as well as accuracy of adjustment of the pressing force of the pressing springs 8. The pump is thus able to determine the condition when it cannot or can ensure the correctness and accuracy of pumping.

[0061] In order achieve pumping, the tubular element 1 is connected into a vessel with the pumped medium and the output hose. The output hose can be used so as to dose the medium into and external or extrinsic system. After switching on the peristaltic rotation pump of the present invention, the pump system fills the hoses and the tubular element by electrical rotation of the rotor 6. In order to adust the volume to be dosed it is necessary to calculate the number of steps of the stepping motor. By pressing a start button, the rotor 6 of the peristaltic rotation pump starts turning and the programmed exact and linear pumping begins.

[0062] The pressure roller 4 of one of the arms 23 of rotor 6 moves along the supporting occlusal surface 3 between the input and output hoses. As the rotor 6 turns, it presses onto the tubular element 1 so as to reduce its cross section. Complete compression of the tubular element 1 by the pressure roller 4 always occurs at the most distant point 28. As the rotation of the velocity of the rotor 6 increases, a higher viscosity of the pumped medium can occur by the proper compression caused by

the pressure roller 4. When the pressure rollers 4 does not connect either of the speed contact 25 with the common contact 27, the electronic system interprets the speed and slows down rotation. As a result, the connection of the position contact 26 (located by approx. 4° in the direction of the rotor 6 rotation in relation to the contact 25) with the contact 27 will occur. This defines the beginning of the occlusal path 2 and also assures the reliability of the compression of the pressure roller for any rotation speed of the rotor 6. As a result, pumping correctness is achieved. The pump, in this mode of operation of maximum pumping, speeds up and guarantees correct compression of the tubular element at the beginning of the occlusal path 2 and, also, assure the accuracy of pumping.

[0063] The pump is thus able to determine and not to exceed the maximum pumping speed. As a result, it guarantees correctness and accuracy of pumping even under variable operation conditions.

[0064] The moment of compression of one of the pressure rollers 4 on the tubular element 1 and also on the contactor 26 the preceding pressure roller 4 is at the end of the occlusal path 2 and at the beginning of the releasing path 16. A further slight turn of the rotor 6 shifts the above mentioned preceding pressure roller 4 toward the releasing path 6. This causes the opening the tubular element 1. Each further movement of the rotor 6 causes progressive release of the pressure roller 4 from the tubular element 1 so as to release a constant volume of the fluid therefrom.

[0065] The pumped medium is forced out of the tubular element 1, and thus out of the pump output by the pressure roller 4, which is moving at that moment on the portion of the tubular element 1 adjacent to the occlusal path 2. The preceding pressure roller 4, which is moving on the tubular element 1 adjacent to the releasing path 16, does not influence the pressure force of the pump since the space within the tubular element 1 before and after this roller 4 is connected and gradually filled with the medium forced by the next roller 4 moving on the tubular element 1 on the occlusal path

[0066] After pumping the peristaltic rotation pump will switch off. By turning the control element 32 of the rotor 6, the pressure blocks 5 slide inside the arms 23 of the hollow profile 7 of the rotor 6. Axial pressure on the rotor 6 causes higher compression of the spring 17 fitted in the hollow cylindrical protrusion 29 of the body 22 against the shaft 9 of the motor 10. The securing pin 21 is released out of the securing groove 19. By turning the rotor to the left the securing pin 21 moves opposite the output groove 20 and the rotor 6 may be pulled off of the shaft 9 of the motor 10. By turning the control element 32 in the opposite direction, the pressure blocks 5 slide out and their pressing springs get partly released. Then, the tubular element 1 is pulled out of the groove of the outer housing 24. The ends of the tubular element 1 can then be removed from the supporting surfaces 15 and 18.

[0067] The foregoing disclosure and description of the invention is illustrative and explanatory thereof. Various changes in the details of the illustrated construction can be made within the scope of the appended claims without departing from the true spirit of the invention. The present invention should only be limited by the following claims and their legal equivalents.